A critique of Ontological Pluralism: the case for *Quantum Mechanics*[1, 2]

Una crítica al Pluralismo Ontológico: el caso de la *Mecánica Cuántica*

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Abstract

Scientifically speaking, quantum mechanics (QM) is the most successful theory ever made. Philosophically speaking, however, it is the most controversial theory. Its basic principles seem to contravene our deepest intuitions about reality, which are reflected in the metaphysical commitments of classical mechanics (CM). The aim of this paper is twofold. First, I argue that QM implies an *ontological* challenge, and not merely an "ontic" one, as it has been traditionally interpreted in the analytic tradition. Second, I suggest that positions known as "ontological pluralism" exhibit an internal weakness due to its unwarranted compromise to a representational view of scientific theories.

Key words: physics, Cushing, Heisenberg, ontology, comprehension.

Resumen

La mecánica cuántica (MC) es, desde una perspectiva científica, la teoría más exitosa jamás formulada. Desde una perspectiva filosófica, es la teoría científica más polémica. Su formalismo desafía principios profundamente arraigados, que consideramos esenciales al pensamiento racional. Mi trabajo tiene dos objetivos. El primero es argumentar que MC implica un desafío *ontológico* y no *óntico*, como ha sido interpretado tradicionalmente en la filosofía analítica. El segundo es sugerir que la posición filosófica denominada "pluralismo ontológico" sufre de una debilidad interna debido a sus compromisos filosóficos con una concepción representacional de las teorías científicas.

Palabras clave: física, teoría, Heisenberg, ontología, comprensión.

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1. Introduction

Scientifically speaking, quantum mechanics (QM) is the most successful theory ever made. Philosophically speaking, however, it is the most controversial. Its basic principles seem to contravene our deepest intuitions about reality, which are most patently exhibited in the metaphysical commitments of classical mechanics (CM).

In the last century many attempts to rejoin CM and QM have taken place, like Bohr's Kantian defense of the priority of classical concepts (1937) or Bohm's search for a classical limit trough the quantum potential 'R' (Bohm 1952). However, most interpretations suffer from one of two main serious difficulties: either they are thought to be *too restrictive* and incapable of appreciating the revolutionary features of QM, or else they are thought to be *too implausible* given the strange ontological commitments required by the interpretation. Ontological pluralism (OP) has become an attractive middle ground between these two poles. A pluralist stance respects the idiosyncratic features of each theory, while at the same time restricts their ontology to what is required by the mathematical formalism.

An important historical example of OP in quantum physics can be found in Werner Heisenberg's book *Physics and Philosophy* (1958). According to Heisenberg, the history of physics is a succession of theories, were each theory is a closed system [*abgeschlossene System*]. It is "a system of axioms and definitions which can be expressed consistently by a mathematical scheme" (Heisenberg 1958 92). In each system, the concepts are represented by symbols which in turn are related by a set of equations, and the resulting "theory" is thought to be "an eternal structure of nature, depending neither on a particular space nor on particular time" (93). Given this systemic closure, each theory generates its own concept of "reality", whose validity is not restricted by other theories.

After Heisenberg, many sophisticated versions of OP have been proposed (Krause 2000; Longino 2002). Most of these approaches disregard Heisenberg's notion of "closed system". However, they all share a common assumption which stems directly from Heisenberg's treatment of physical theories, and has been barely discussed. I will call this assumption the "Comprehension Thesis" (CT). According to the CT, to "understand" or "comprehend" something is to relate a multiplicity of elements trough a finite number of non-arbitrary relations. The *local* version of this thesis is that *each theory must be internally comprehended*. This is typically achieved through the fixation of the referents of some of the theory's symbols. The symbols are then related to non-symbolic items trough what I call "principle of referential persistence" (PRP). A symbol

Ψ persistently refers to an item of the world E iff Ψ refers to E in every occurrence of Ψ. When each symbol becomes "attached" to its referent, the resulting articulation constitutes the ontology of each theory.

Although defenders of OP typically ascribe to CT and PRP, the pluralist denies any *global* application of CT, since this would imply an inter-theoretical reduction of the many languages, methods and metaphysical commitments into one total theory (or ToE), and the rejection of such a theory is precisely the starting point of any ontological pluralism.

The aim of this paper is to show how this restricted use of CT is unwarranted. Since OP lacks any alternative conception of "comprehension" for global cases, any restriction of CT to the local case shows itself to be arbitrary. As the argument develops, it will be suggested that the main reason for this internal weakness is that OP upholds, along with scientific realism, a representational conception of scientific theories according to which a theory is a *description* of physical reality. This commitment is obviously manifested through the maintenance of PRP. It will be argued that the central problem with ontological pluralism is that this restriction of CT is incompatible with its own representational conception of scientific theories.

So the pluralist must choose: either she abandons CT altogether or she fully applies it. If she chooses the former option, it is impossible to distinguish ontological pluralism from an *instrumentalist* account of scientific theories, since the problem of comprehending those theories as *being about something* would be completely obliterated. If, on the other hand, she chooses the latter alternative, then she is confronted with a reductive account of physical theories, since her holding of PRP makes it impossible to avoid a Theory of Everything. As a conclusion, I suggest that the only viable way to preserve scientific realism and avoid a reductive account of global comprehension is to abandon PRP in favor of a more dynamic account of the way in which scientific theories relate to the physical world.

2. Quantum mechanics and "the ontological question"

It is commonly held that quantum mechanics (QM) constitutes a philosophical challenge due to the fact that its formalism entails the strangest ontological commitments. We speak of "superposition states", "indistinguishable individuals" or "probability waves" as sorts of entities which we don't fully comprehend, although being thoroughly "described" by the mathematical structure of the theory.

But how are we to understand the word "ontological" here? For those working within the lines of analytic philosophy, a good choice would be to defend a Quinean understanding of the problem, famously summed up in the simple interrogative: "What is there?" (Quine 1948). Since Quine's famous formulation, virtually every philosopher in the analytical tradition has though the ontological question in exclusively extensional terms, *i.e.*, as a problem concerning the *extension* of some domain, namely, the set of existing things in the Universe. If this is so, then the ontological challenge represented by QM would be the challenge of understanding how can there be such things as "superposition states", "indistinguishable individuals" or "probability waves" in the Universe. But as Taylor has already observed, this formulation of the ontological question is "notoriously misleading", since "it suggests that we are already quite clear as to what "Being" is, i.e. as to what we mean when we say of something, that it exists" (125).

Let me clarify this point. Each scientific discipline involves the definition and delimitation of its own object of inquiry (physical bodies, organisms, societies, etc.). In the course of their development, most of these disciplines have changed, producing *shifts* not only in the technical and methodological principles governing them, but also (and especially) in the domain of entities accepted by the current scientific community. This may happen through the *introduction* of new entities (like the gene in Mendelian genetics) or through their *elimination* (like phlogiston in Lavoisier's theory or Aether in Einstein's special relativity). However, the shift required by QM is strikingly different, since its postulates seem to defy the most basic principles concerning our understanding of Nature. This was what Heelan (1975) meant when he wrote that "such changes as quantum mechanics proposed affected not merely the content of physics but the very notion of science itself" (125). In other words, QM does not only require an extensional shift of the domain of physical entities, but also requires *an ontological shift* concerning our very notion of "entity". If we ignore this radical dimension, we will fall short of comprehending what I have called "the ontological question". This question should not be formulated as one about the existence of some sort of entity in Nature, but rather as the possibility of having in view *another* notion of "entity". So one could speak of this "ontological shift" as one that involves the consideration of two distinct "ontologies" (in this more profound sense of the term): on the one hand, a "classical ontology" or "O_C"; on the other hand, a quantum ontology or "O_Q". Paraphrasing Kuhn, one could assert that the classical physicist and the quantum physicist "live" in two different Natures.

This being said, the "ontological question" should be understood as a question about the relation between O_C and O_Q. As we will see later, different answers to these questions will imply different philosophical attitudes towards quantum physics. In particular, "pluralism" should be understood as the thesis that *both* O_C and O_Q can stand each one in their respective domains. In order to stress the fact that this is a *metaphysical* thesis, we ought to use the expression "ontological pluralism" (OP) instead of more frequently used labels as "scientific pluralism" or "theoretical pluralism" (*cf.* Bokulich 2004). But before focusing on OP we must first discuss the different features of both O_C and O_Q in more detail.

3. Three principles of classical ontology

It would be difficult to argue for a *single* "classical ontology" in the history of Western thought. However, once we make the ontological distinction and pose the ontological question in its rightful place, we may observe that although many things have changed over the centuries, the classical definition of an "entity" has stayed relatively stable since Aristotle's *Metaphysics.* We could sum up this "classical understanding" of the entity in three basic principles which I will call actuality, individuality and identity.

The *principle of actuality* states that an entity is something *determined*. Its formulation can be traced back to Aristotle's exposition of the law of non-contradiction (*Met.* 1005b 19-20). Aristotle observed that the most general thing that can be said about an entity is that *it is something*. Obvious as it may seem, this observation has two important metaphysical implications. First, it supposes the ontological validity of the principle of non-contradiction, for if we are to say something *determinate* about an entity we cannot say that it has a property P and *at the same* time that it doesn't have it. Aristotle's main argument for this conclusion is that "if all contradictory propositions were true at the same time in respect to the same thing, then clearly everything will be one" (*Met.* 1007b 18-21). If everything was one, then it would be useless to ask about something *what it is*, since it would be everything. Secondly, it also supposes the validity of the law of excluded middle: "of one subject we must either affirm or deny any one predicate" (*Met.* 1011b, 25-30). To say that something is determinate is to say that it has *determinate* properties, and if we couldn't say of an entity if it is P or not, then we would not be able to say something determinate about it. These abstract features are condensed in the highly complex notion of "actuality" (ἐνέργεια). An actual entity is a determined entity, as opposed to a potential one, which could in principle tolerate opposite determinations simultaneously (*cf.* Lukasiewicz & Wedin 501).

The second principle, which I have termed *individuality*, states that a determinate entity is to be considered as an *individual*, so that it can always count as one.[5] This principle, in turn, supposes the validity of Leibniz law, for if we are to determine an entity E, we must in principle be able to find at least one property P so that:

(i) P_E

(ii) $P_X \supset x = E$

We are heirs to a long tradition according to which every entity can be particularized in virtue of its properties, so that we can distinguish one entity from another by naming or "labeling" them (Redhead & Teller 1992 201-202; Krause 157).

Finally, the *principle of identity* establishes that the entity is the same through the change of its properties. Graphically, this relation is usually though as a kind of "nuclear" thing and its many "orbital" properties. Etymologically, this picture is condensed in the word "substance", which comes from the Latin "*sub-stare*" which means "to stand under", hence "to persist". So I will call this a "substantial structure" of identity. Although identity and individuality are sometimes considered together it will be useful to distinguish the question of the latter as an inter-specific question concerning the relation *between* entities, and the question of the former as an intra-specific question concerning the entity's relation to *its own* determinations.

These three principles can be thought as constituting a core common-sense about physical reality. A noteworthy example of this common-sense can be found in a letter sent by Einstein to Max Born on 12th May 1952, while discussing the problem of locality in Bohm's interpretation:

> An essential aspect of this arrangement of things [in a space-time continuum] in physics is that they lay claim, at a certain time, to an existence independent of one another (...) Unless one makes this kind of assumption about the independence of the existence of objects which are far apart one another in space (...) physical thinking in the familiar sense would not be possible (Born , 170)

Although Einstein was not primarily concerned with our current discussion, it is clear that his realist defense of physical science involves a "classical understanding" of the notion of "entity". Einstein is in fact known for having adopted a "conservative" stance towards quantum physics, especially in regard to the possibility of constructing a realist interpretation of the formalism.

5 For further analysis on the relation between "individuality" and "countability", see Cushing (1994) and Lowe.

This was not the case for Heisenberg, who did thought that QM described a "reality" of its own. But before moving to Heisenberg's theory, we must analyze the way in which quantum phenomena defies this "common-sense view" about physical reality.

4. "Quantum" challenges for classical ontology

All the three classical principles mentioned above face serious difficulties when we try to employ them in our understanding of QM. In order to remain systematic, I will briefly mention three respective "counter-principles" of O_Q, namely: the principle of contextuality, the principle of contraction and the principle of duality.

First, consider quantum *contextuality*. Suppose we have a quantum system S_{AB} with two incompatible observables represented by two non-commutative operators $\hat{O}_A$ and $\hat{O}_B$. Suppose that $\hat{O}_A$ represents "momentum" and $\hat{O}_B$ represents "position", and that each operator has three possible values: $\{a_1, a_2, a_3\}$ and $\{b_1, b_2, b_3\}$, respectively. Given Heisenberg's uncertainty principle, we know that we cannot measure a determinate value for both properties simultaneously. So we say that momentum and position belong to different contexts. And we can define a *context* as a subset of observables of a quantum system represented by commutative operators (Karakostas). Furthermore, given the Kochen-Specker theorem, we know that we cannot consistently assume that a determinate measurement will be possible for two observables belonging to different experimental contexts.

How is contextuality encountering the classical principle of actuality? We have seen that in O_C the entity is thought as being actual, i.e., as having determinate properties. This in turn entailed the validity of the law of excluded middle, since for every property P, either the entity has it or it doesn't. There is no "hesitation answer" to the question "Does E has P?" Hesitation would be at best a subjective state: we do not *know* if E has P. The problem with quantum contextuality is that we cannot interpret hesitation as a subjective state. The Kochen-Specker theorem frustrates every direct attempt to understand indeterminacy as an epistemological limitation, because there is no hidden-variable theory that would give us the complete set of determinate properties independently of any context. This is why some have argued for an "irreducible indetermination" in quantum reality (*cf.* Lombardi & Pérez 2012 148-155). If this is so, then we cannot sustain the law of excluded middle since we must accept that if S_{AB} *has* a determinate momentum, then its position must be *literally* undetermined.

The second principle, which I call *principle of contraction*, poses a serious difficulty to classical individuality. It has already been noted that the existence of the so-called "identical particles" in quantum physics requires a radical reformulation of the idea of an "individual" (French & Krause).

Suppose an experimental arrangement for measuring the energy state of two bosons, 'a' and 'b'. Suppose, in addition, that there are two possible energy states for each boson, E_1 and E_2, which represent discrete magnitudes determined by Planck's constant (85-94). In a classical understanding, the probability distribution would be as follows:

	E_1	E_2	P
1	a	b	P(1) = ¼
2	ab		P(2) = ¼
3		ab	P(3) = ¼
4	b	a	P(4) = ¼

But since 'a' and 'b' are indiscernible we cannot even "label" each boson, although we "know" there are two of them. However, this might not threaten the idea of individual particles. One could think that both 'a' and 'b' are in fact individual particles, even if we cannot label them. If this were so, the probability distribution would be as follows:

	E_1	E_2	P
1	**		P(1) = ¼
2	*	*	P(2) = ½
3		**	P(3) = ¼

In this case probabilities are reduced to three, since P(1) and P(4) have become indistinguishable. So P(2) represents the addition of two *different* probabilities (¼ + ¼ = ½).

However we know that classical "Maxwell-Boltzmann" statistics does not apply in the case of bosons. The experimental outcomes show another kind of probability distribution called "Bose-Einstein statistics":

	E_1	E_2	P
1	**		P(1) = ⅓
2	*	*	P(2) = ⅓
3		**	P(3) = ⅓

How are we to interpret these results? Philosophically speaking, it must be recognized that this probability distribution is at odds with our intuitive ideas about individuality. Since the first distribution does not obtain, we must admit that 'a' and 'b' are indistinguishable. But since the second distribution does not obtain either, we cannot interpret this limitation epistemologically. The principle of *con*traction forbids the *abs*traction of thinking two individual entities in the context of quantum mechanics. *What* is not at all clear is what we should think about, instead.

Finally, *the principle of duality* is at variance with the classical principle of identity. As Grossman concisely puts it:

> The history of physics seems to indicate the belief that the presence of change must be explained on the basis of something which does not change. That which remains invariant under a given transformation is always regarded as belonging to a deeper level of reality than that which undergoes the transformation (88).

In metaphysical terms, this means that a *thing's* identity remains invariant (it maintains invariant properties) through changes in its (non-essential) determinations. However, in the famous double-slit experiment the entity labeled "electron" seems to radically change all its (essential and non-essential) properties when the number of opened slits is changed. This fact "is the crux of all attempts to make 'sense' out of quantum mechanics" (80). According to Grossman's diagnosis, if we are to maintain classical identity, we should seek for something "deeper" which would ontologically explain the discontinuous changes in the "upper" level.

But as we have seen, these "deeper level" would contain entities which are *contextual* (they do not exhibit classical determination) and *contracted* (they are not individuals, strictly speaking). This is why Heisenberg declared that wave-particle duality cannot be explained in terms of "relations between objects existing in space and time" (Heelan 1975 49), as was Einstein's aspiration. Though "being measured", for instance, is supposed to be an external determination of an entity, the change in the measurement arrangement will determine if the electron exhibits "wave properties" or "particle properties", which "are too different to be simultaneous properties of the same thing" (80).

In other words, it seems we should discard the notion of "the same thing" *without discarding the notion of properties being instantiated.* This leads to an inversion of the "substantial structure" of identity mentioned above, since we lack that "substantial" element which is supposed to "stand under" both the wave and the particle properties.

5. Ontological pluralism as "the best of both worlds"

The perplexity raised by what I have called "the ontological question" leaves us with one vital question: how are we to understand the relation between both ontologies? If we consider this question from the ontological perspective outlined above, we get a sort of metaphysical disjunction ("O_C or O_Q") from which we must consider the three logically possible answers:

a. Drop O_C and retain O_Q
b. Drop O_Q and retain O_C
c. Retain both O_C and O_Q

(a). The first strategy would be to disregard quantum mechanics as a theory about *the world*, and thus preserving traditional Aristotelian logic and metaphysics. In fact I believe that the "Copenhagen Interpretation", today's dominant interpretation of QM, falls into this option. Although it is dubious to speak of *one* Copenhagen Interpretation (*Cf.* Howard) it is clear that all of them share the notion of "complementarity" as a starting point.

Following Kant, Bohr argues that human experience is classic: individual entities which are determined and identical to themselves. In so far as in physics the experimental stance is needed, it cannot give up this macroscopic ontology. Otherwise, it would lose its possibility to communicate the different experimental results. In the case of quantum physics, however, we must renounce classical ontology since "it is no longer possible sharply to distinguish between the autonomous behavior of a physical object and its inevitable interaction with other bodies serving as measuring instruments" (Bohr 1937 290). As each experimental arrangement directly affects the measured system, QM introduces a fundamental discontinuity which is reflected in the wave-particle duality. Since wave and particle are both classical concepts which exclude one another, their application to the quantum realm is somehow inappropriate. But we cannot but use them if we are to communicate our experimental results, since "every word in the language refers to our ordinary perception" (Bohr 1934 91). The idea of *complementarity* is thought to constitute an answer to this paradox (or "irrational feature of the postulate" as Bohr himself calls it) because with it we are able to understand the incompatibility of both images, but also their need in order to give "an exhaustive account of all experience" (Bohr 1937 291).

Bohr's attempt to preserve the primacy of OC becomes evident in the "wave function collapse" postulate, according to which a measured quantity is forced to a particular eigenstate by the measuring act itself (in this case, the modification of the number of opened slits). With the Kantian-inspired restriction of complementarity, Bohr dismisses the possibility that QM gives an objective account of Nature, since both the measurement instruments and the quantum system are indistinguishable, and "the formation of human ideas [is] inherent in the distinction between subject and object" (Bohr 1934 91).

(b). The second strategy would go in the opposite direction, i.e., discarding O_C in the light of the features of O_Q. For instance, one may trace this tendency in Hilary Putnam's famous essay *Is Logic Empirical?* Here, Putnam suggests that empirical evidence provided by quantum physics should be a sufficient reason to conclude that "it is more likely that classical logic is wrong" (189). In other words, to solve the problem of *understanding* quantum mechanics we should recognize that classical logic was, after all, an inadequate formalization of the relations which take place in Nature, and therefore a new logic should be adopted. This "quantum" logic would be such that, for instance, the distribution law does not obtain (since, of course, Leibniz law does not obtain either).

(c) The third strategy, which I have called ontological pluralism, is the one I am interested in discussing. Pluralism has gained currency especially after the demise of logical empiricism and its project of reducing the sciences under one explanatory model. Ontological pluralism (OP), by contrast, "takes each scientific theory to have its own distinct domain of laws, entities, and concepts, which cannot be reduced to those of any other theory" (Bokulich 2001).

Following a rough classification, we could envisage three main arguments in favor of ontological pluralism: first, a historical argument; second, a heuristic argument; and finally a metaphysical argument.

The historical argument was famously put forward by Kuhn and Feyerabend (1988). Kuhn's famous thesis of incommensurability and his view of scientific historical progress as a discontinuous succession of paradigms had an immense impact for the pluralist account of scientific knowledge. Since terms as "space" of "body" radically change their meaning from one paradigm to another, it is no longer possible to reduce one theory's language to another. Paul Feyerabend, echoing J.S. Mill's famous essay *On Liberty* (1859/1990) and Hegel's historical-developmental view of human knowledge, argued that if we look at the history of science, we will not find a unitary, rational approach to the world, but rather an "ocean of mutually incompatible alternatives" which work simultaneously for "the development of our consciousness" (1978 21).

The second kind of argument focuses instead on the practical advantages of maintaining a plurality of different (and even incompatible) theories. Hasok Chang (2012) has recently argued that each theory is "part of a coherent system of scientific practice. None of those systems should be given the right to suppress, exclude, or delegitimize the others, because we need all of those systems to give ourselves maximal exposure to reality" (15). If we have a plurality of different approaches to the real world, we diminish the risk of imposing *a priori* restrictions motivated by metaphysical or ideological prejudices. Einstein's reaction to the nonlocal character of QM mentioned in section 2 can be seen as an example of what Chang means here. In fact, as I have argued, it is his maintenance of O_C which motivates his critique of Bohm's interpretation of QM.

The third type of argument has been clearly put forward by Nancy Cartwright (1994). In her opinion, "all evidence points to the conclusion (…) that Nature is not reductive and single-minded. She has a rich, and diverse, tolerant imagination and is happily running both classical and quantum mechanics side-by-side" (1994 361). So, as Bokulich (8-14) rightly argues, her contention is based on metaphysical rather than epistemological grounds. For Cartwright, the idea of a unitary of "single-minded" Nature is no more than an unwarranted metaphysical commitment which in fact should be questioned in the light of the actual plurality of scientific theories.

So OP becomes an attractive middle ground between the other two poles. A pluralist stance respects the idiosyncratic features of each theory, while at the same time restricts their ontology to what is required by the mathematical formalism. In the case of physics, the pluralist is able to recognize that O_C is essential to understand macroscopic processes while at the same time O_Q becomes indispensable in the subatomic world, *without the need* to place both ontologies under a single framework. Here the expression "world" should be interpreted in a fairly strong sense, i.e., as if each theory "constituted" its own world.

An exemplary case of OP in the classical-quantum debate is to be found in Werner Heisenberg's philosophical book *Physics and Philosophy*, where he argues that the history of physics is a succession of different theories, each of them being a "closed system" [*abgeschlossene System*]. A "closed system" or "closed theory" is "a system of definitions and axioms which can be written in a set of mathematical equations" where each sharply-defined concept is represented by a particular symbol and each symbol is related to a certain "field of experience", so that the whole system may be considered as "describing an eternal structure of nature, depending neither on a particular space nor on particular time" (92-93).

According to this definition, these systems exhibit three main features. First, a closed system is *axiomatic*, in the sense that the possibility of formalizing a set of concepts and relations is a necessary condition of every physical theory. Second, the system is *holistic*, because the concepts are so firmly related to each other that "one could generally not change any one of the concepts without destroying the whole system" (94). Thirdly, a closed system must be considered *final* in the sense that its laws "describe certain features of nature that are correct at all times and everywhere" (99). It is in virtue of these three features that the system is thought to be an "eternal structure of nature". Each system structures its proper domain, and therefore generates its own notion of "reality". In other words, each system constitutes a differentiated *ontology*, not just by providing an inventory of real entities, but by redefining in each case the very notion of reality itself.

Heisenberg, for example, defines Newtonian physics as "the ontology of materialism" (145) whose worldview consists of an objective structure composed by actual entities, just like in Einstein's description. By contrast, Heisenberg thinks that the "entities" portrayed by the formalism of QM should be understood in terms of the Aristotelian notion of potentia [δύναμις]. In the Aristotelian ontology, potentiality is related to change and the indeterminate matter. Since a *potential* entity is indeterminate, it lacks the features we usually ascribe to determinate entities: individuality, identity, non-contradiction. Thus, the paradoxical aspect of the "wave-particle duality" fades away once we recognize that a state such as a quantum superposition is not composed by actual entities (like "waves" or "particles") but rather by "indeterminate" entities which "form a world of potentialities or possibilities rather than one of things or facts" (185-186).

6. Ontological pluralism and scientific understanding

As Bokulich observes,

> (...) the picture that starts to emerge from Heisenberg's account of closed theories is a kind of *theoretical pluralism*: contemporary science is characterized by a handful of distinct closed theories, each with its own circumscribed domain, within which the theory is perfectly accurate and unalterable (7).

From this point of view, Heisenberg's pluralism rests in a sort of inter-theoretic tolerance, since "future research then cannot falsify a Closed Theory; it can only discover restrictions on its domain" (Heelan 1975 7). This is why some have observed the close similarity between Heisenberg's notion of *abgeschlossene* System and Kuhn's idea of "paradigm" (*cf.* Beller; Bokulich).

Yet other features become visible here. OP poses a specific strategy for *understanding* a scientific theory, since in order to understand a theory T we ought to ask *how the world* is according to T. And this is done by providing a thorough analysis of T's *language*, i.e., its basic terms and concepts. So we must look at the several symbols present in T's language and ask what those *symbols* are standing for.

James T. Cushing (1991; 1994) has provided a very interesting insight concerning the concept and nature of scientific understanding. He distinguished three different levels of scientific discourse: (*a*) empirical adequacy, (*b*) explanation and (*c*) understanding. *Empirical adequacy* consists essentially in "getting the numbers right", in the sense of providing an algorithm which is capable of reproducing observed data and measurements (1991 338). An example of this would be Planck's constant *h*, which describes mathematically the observed relationships between energy and frequency. *An explanation* "is provided by a successful formalism with a set of equations and rules for its application" (1994 10). Explanation in this sense is understood "in terms of entailment" and becomes equivalent to the so-called deductive-nomological model (10). This level would correspond to Heisenberg's notion of a closed system, i.e., a set of applicable formulas. The third level is that of *understanding*, which "produces in us a sense of understanding how the world could possibly be the way it is" (11). Understanding is achieved through the interpretation of the formalism.[6] This would correspond to Heisenberg's metaphysical interpretation of the "closed system" known as quantum mechanics in terms of Aristotelian potentialities.

Cushing cites Heisenberg's suggestion as an attempt to increase our understanding of quantum phenomena (1991 348). However, it should be noted that Heisenberg is not the only one to adopt this strategy. Cartwright (1994), for example, states that the intelligibility of an interpretation must be addressed by asking *what does* the quantum wave function Ψ represents (55). Krause has also provided a similar strategy. He adopts a strange ontology of "non-individuals", and defines a non-individual as "an entity for which it makes no sense to say, among other things, that it is equal or distinct from others of the same species" (162). He then argues that some symbols such as the numeral

6 Cushing describes understanding as a "pragmatic bonus" in scientific explanation, in so far as it depends on contextual factors that determine our sense of understanding as human beings (1991 340). However, he argues that some features of understanding as such are susceptible to an objective description. One of these features is *picturability* (341), *i.e.*, understanding must involve picturable physical mechanisms. While I mostly agree with his contention that understanding involves the need for a picturable model of the world, I believe that this is enough in order to give a *formal* definition of *comprehension*, while Cushing thinks it necessarily entails an atomistic, casual and mechanistic picture of the world (351-353).

'6' in the formula for the sodium atom ($1s^2 2s^2 2p^6 3s^1$) should be regarded as representing "non-individuals", which in this case are electrons (163).

My contention is that the idea of providing a *comprehensible picture of the world* by relating the diverse symbols of the theory's language as *representing something* is idiosyncratic to OP. Note that there are two related issues here: first, what it means to understand something in general, and second, how understanding is achieved through a scientific theory. The relationship between these two assumptions and OP has received scant attention. However, it is possible to provide a general characterization of both of them.

I will call the first assumption "comprehension thesis" (CT). According to CT, to "understand" or "comprehend" something is to relate a multiplicity of elements trough a finite number of non-arbitrary relations in a single system. This is already indicated in the etymology of the word "comprehension": it comes from the Latin compound of "con" and "*prehendere*" which literally means "to put together, to reunite". So something is said to be (rationally) comprehended when some set of elements (which may appear as indifferent to each other) *are brought together* in a single set of relations. This is a fairly intuitive description of what understanding means. But this is not enough.

In the case of scientific theories, comprehension is typically achieved through *the fixation of the referents* of some of the symbols in the theory's language. Those symbols are then related to non-symbolic items –they are given "an ontic status", in the words of Cushing (1991 348). Once a symbol is fixed to an "entity" (in the broadest sense of the term) that referential relation *persists*. I call this "principle of referential persistence" (PRP). A symbol Ψ persistently refers to an item of the world E iff Ψ refers to E in every occurrence of Ψ in a theory T. When each symbol becomes "attached" to its referent, the resulting articulation constitutes the *domain* of each theory.

The core of the present discussion focuses especially on this idea of "comprehension" behind OP. In this regard it must be asked in what sense the pluralist is able to make quantum mechanics *comprehensible* for us. Since, as I have tried to show, OP maintains CT, we should ask to what extent does the pluralist exploit CT and why.

OP provides a comprehensive picture of the quantum world by applying CT to QM's formalism. This application seeks to *comprehend* the theory's multiple expressions (superposition, spin, "wave", particle, etc.) under a single domain by relating those multiple expressions in a non-arbitrary way, i.e., in a way that each occurrence of those expressions makes sense as a part of *a quantum reality*, albeit a very bizarre one. This attempt to gain an understanding of the quantum world distinguishes OP from a merely instrumentalist approach, which Huw Price (1992, 405) characterized as an "ontological asceticism". OP and instrumentalism are distinct in that the former is concerned with ontological issues while the latter is not. Indeed, it is precisely because the pluralist provides an "ontological picture" for each theory that she considers her effort as an intellectually valid one. Take, for example, Ronald Giere's definition of *scientific understanding*:

> I understand theorizing as the construction of models. (…) Often, as in physics, abstract models are characterized *using interpreted mathematical expressions* (…). The world seems to be such that specific models structured according to the principles can be made *to exhibit a close fit with systems in the real world* (Giere, 32 my emphasis).

This, of course, does not imply that there is *a single* model of reality. In fact, OP rests on the denial of such a possibility. Giere, for example, proposes a "perspectival pluralism" in which "the only adequate overall picture will be collages of pictures from various perspectives" (Giere 28). This, however, does not make the pluralist drop CT altogether, because she restricts its application to a "local" level. A *local* version of CT is the thesis that each theory must be *internally* comprehended –in the technical sense of comprehension sketched above.

However, this raises a further issue. Can we maintain *a realist* conception of physical science under OP's restriction of CT? At first, it would seem as we have lost any possibility of understanding both classical and quantum mechanics as descriptions *of nature*. It would seem that CT and PRP need to be maintained also in a global level, if we are to conceive science as a kind of knowledge whose limits "are made not by any group of scientists but by nature itself" (Heisenberg, 194).

An obvious response to this objection would be to deny the need of unification in order to make O_C and O_Q comprehensible. In fact, this is precisely the aim of OP's metaphysical argument: to show that there is no reason to suppose that nature is "single-minded". So the need for a global application of CT would be supported by what Kellert, et al (2006) calls a "mistaken ideal", namely, "that successful science must offer a comprehensive and global theory of the phenomena being investigated" (192).

However, this well-known answer faces some difficulties once we have recognized OP's own account of scientific understanding. First of all, the pluralist must explain *her actual use* of CT in the local level. Why should we accept CT straightforwardly in a local level and at the same time deny it in a global one? Moreover, the pluralist must equally explain her use of the expression "physical science" to both classical and quantum mechanics. If each theory "has its own world", i.e., if they are conceived as systems that generate their own notion of "reality", why should we call both worlds "physical"? In a word: it would seem that if OP uses CT, then its restriction is unwarranted.

Once we get to this point, OP's only criterion to describe both theories as "being about nature" would be merely pragmatic. This, for example, is the case with Giere, who recognizes that the idea of "a single world with a unique structure" is a *methodological maxim* which tells us to proceed "as if there is a single world with a unique structure" (1999 32). On a local level, then, both CT and PRP help us to *understand* what a theory is talking about. The multiple symbols are interpreted as referring to some aspect of a unitary phenomenon, i.e., the world according to that theory. But in a global level, we must instead settle with the idea that CM and QM must be thought *as if* they described the physical realm. But this would simply mean that we have given up the possibility to *comprehend* the relationship between O_C and O_Q.

Let me clarify this point. The fact that OP works with a notion of "understanding" which makes it unable to comprehend the relation between two ontologies does not prove that pluralism is wrong. Neither has it demonstrated, against Cartwright, the truth of the metaphysical thesis that there is one Nature. The point is rather that there is an internal tension in OP given its own criteria of understanding, which I have described as a compound of CT and PRP. In a nutshell: if we consider OP's own presuppositions, we must say that Nature is, as such, incomprehensible, even if we accept Cartwright's suggestion that Nature is "plural".[7]

So the pluralist must choose: either she abandons CT altogether or she fully applies it. If she chooses the former option, it is impossible to distinguish ontological pluralism from an *instrumentalist* account of scientific theories, since the problem of comprehending those theories as *being about something* would be completely obliterated. But the other option seems equally inconvenient for the pluralist. Given her maintenance of PRP, an unrestricted application would imply the need to bring *all* symbols under an interpretation, so that their referents become fixed. But given the global application of CT, this would mean that every symbol would be related to each other as a part of a unitary language whose sole referent would be *the* world as a comprehended

7 This line of argument is indeed very close to Cushing's concerns. However, unlike Cushing, my contention is that in its actual stage of development, OP would not help us to gain understanding not because its picture is not mechanistic (as he would argue) but rather because it has no way of constructing a single picture. That single picture need not necessarily be a mechanistic one.

unity. This, of course, would leave us with a "Theory of Everything". This is precisely why the advocates of OP restrict their application of CT.

It seems, then, that the main reason for this internal weakness is that OP upholds a representational conception of scientific theories according to which a theory is a *description* of physical reality (whether this reality is single-minded or not). This commitment is obviously manifested in the maintenance of PRP.

6.1. Afterword: giving up representation

The main question of this paper has been about the possibility of *understanding* different ontologies. In particular, the case of quantum mechanics is appealing because it suggests that OP is incapable of making sense of the relationship between two distinct ontologies. The problem of QM itself arises because we are already devoted to the idea that physics describes the physical world, while the features of QM's formalism strike us as strange and incomprehensible. But the more general problem is precisely the idea of "comprehension" lurking behind OP's presuppositions.

The classic examples of global comprehension of theories are thought under the nomological-deductive model, so that comprehension implies derivability. The best-known example is that of the reduction of thermodynamics to statistical mechanics, as was put forward by Ernest Nagel in his famous book The *Structure of Science* (1961). After Nagel, a vast number of scientists and philosophers of science criticized his model. Many argued that there are no historical examples of Nagelian reduction (*cf.* Sklar; Scerri and McIntyre). Others criticized its application to other disciplines such as biology (Kitcher 1984; Rosenberg) and psychology (Fodor).

This long tradition makes it easy to understand why the idea of a "global comprehension" is seen by the pluralist as an old-dated reductionist pretension which has no philosophical attractive whatsoever. Hence, a pluralist such as Alan Richardson argues that "an internal ontology within any style of reasoning is our only place to speak of ontology at all" (8).

But does global comprehension really imply inter-theoretical reduction? In some cases, the need for a global comprehension is related not with the reduction of a theory to another, but rather with the *rise* of a new discipline. Why is it, for example, that modern anthropology replaced theology as an explanation of human reality? The anthropological sciences were developed out of the need to integrate human being to the *same world* other sciences talked about. As Eller (2007) concisely put it: "If mind, body, society, culture, nature, and supernature are all dimensions of an integrated system, then we should expect to find connections between and reflections of each in the others" (147). If we had to use Heisenberg's own terms, we would say that as long theology was "isolated" [*abgeschlossene*] it could not survive as a *comprehensive* explanation of human phenomena.[8] Vitalism had a similar fate in relation to biology (*cf.* Prigogine and Stengers).

However, none of these "new" disciplines was actually reduced to another. They preserved their autonomy, but nevertheless they gave us *already* a sense of understanding. Thus, reduction is not a unique way to global comprehension. Nor is it the most frequent, as we have seen.

Rather, global comprehension occurs because we are able to explain some features of the world in terms of other features of *the same* world. This "explanatory immanence" is pervasive even in contemporary philosophy of science. We call it "naturalism". Even the most enthusiastic pluralists are self-described as naturalists. Giere (38), for instance, defends naturalism as "the most fundamental framework" of scientific activity. This allows him to reject appeals both to supernatural entities and *a priori* claims. In a slogan: nothing explains Nature but Nature itself. Even though naturalism does not imply a unified theory of nature, it does imply the idea of a *single natural system*, for if we had several, non-connected natural systems, we could easily defend any form of supernaturalism. But again, since Giere cannot take an ontological stance towards this idea, he must also interpret naturalism as a *methodological stance* which is justified "to the extent that it can be justified at all, simply by appeal to past successes. We have explained life scientifically. Why not consciousness?" (39).

But I believe Giere is not taking the need for a naturalist account seriously enough. The need to explain life or consciousness in terms of natural phenomena is not motivated by the fact that we were successful before. This justification presupposes that we already know what a "successful explanation" means, and this is just precisely the issue under discussion. Giere is obliterating the only relevant question: Why those past explanations were successful at all?

Here, the demand for a unified system seems to be stronger than just a methodological thesis motivated by a historical induction; and arguably weaker than an *a priori* and eternal condition of the understanding. Rather, it would be what Cushing calls "contingently necessary conditions for understanding" (1991 349). This does not exclude the possibility of formulating an

8 Of course this reason is not exhaustive. As has been rightly pointed out by Cushing, there are "subjective and ineliminable" criteria which can have a decisive importance in theory-election processes (Cushing 1994 7).

alternative concept of "understanding", but this is not certainly something ontological pluralists have done.

If this is so, then OP cannot simply drop CT. It seems, then, that the only viable way to preserve comprehension in an ontological level without appealing to reductionism is to abandon PRP in favor of an alternative account of the way in which scientific theories relate to the physical world. Although the exposition of such an alternative obviously exceeds the scope of the present discussion, let me suggest that there is a good reason to drop PRP.

In order for referential persistence to take place, two conditions must be fulfilled: first, it must be possible to make a distinction between the representation and that which is represented. In the case of referential persistence, what is needed is the possibility to identify an item as a representation (e.g., the symbol 'e') and another item as that which is represented (an electron or the class of electrons). Second, it requires that both the symbol and the item represented by the symbol retain their identities through time. Only then we can say that *a* symbol S persistently refers to *an* item E in every occurrence of the symbol in question. Both conditions are straightforwardly satisfied within O_C, where the principles of actuality, individuality and identity obtain. But it is clear from the discussion above that, within O_Q, both requirements become difficult (if not impossible) to satisfy. What becomes clear from this is that OP's maintenance of PRP reveals a vestige of classical ontology *within* pluralist accounts of ontological diversity.

If OP is to succeed in giving us a compelling way of understanding incompatible ontologies, it must first revise its own presuppositions. If not, pluralists will let ontological prejudice preclude the possibility of understanding.

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